# Wind Energy Pultruded Laminate

Mechanical Data Sheet · GFRP and CFRP pultruded spar-cap laminates · Tested to ISO 527-5 / 14125 / 14126 / 14130 / 13003, ASTM D7078, and ISO 11357-2 with characteristic values per DNVGL-ST-0376 and GL 2010.

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| **Document** | F1-TDS-WIND-001 |
| **Revision** | 2026-05 |
| **Grades covered** | WE-G80 (GFRP / epoxy) and WE-C100 (CFRP / epoxy) |
| **Application** | Pultruded spar-cap laminates for wind turbine rotor blades |
| **Test basis** | Independent DNV·GL-accredited laboratory, China |
| **Certification reference** | DNVGL-ST-0376 (Dec 2015) and GL 2010 — rotor blades for wind turbines |

## 1. Scope

F1 Composite pultruded laminates for wind turbine rotor blades are supplied in two grade families: **WE-G80**, a high fibre-content glass / epoxy laminate, and **WE-C100**, a unidirectional carbon / epoxy laminate. Both grades are pultruded continuously to wind-blade spar-cap geometry and are characterised by independent third-party laboratory testing accredited under the DNV·GL renewables-certification scheme. Characteristic values ($R_k$) are reported using the DNVGL-ST-0376 (Edition December 2015) and GL 2010 statistical methods, which is the form required by blade design and certification bodies.

## 2. WE-G80 — GFRP pultruded laminate

WE-G80 is a high glass-content unidirectional pultruded laminate engineered for spar caps in medium and long wind blades where stiffness-to-cost is the primary driver. The reinforcement is boron-free E-glass roving; the matrix is a bisphenol-A epoxy system with a service-tested cure profile for continuous pultrusion. Specimen preparation and conditioning follow ISO standard practice.

### 2.1 Physical properties

| Property | Standard | Unit | Avg | Rk (DNVGL-ST-0376) |
|---|---|---|---|---|
| Fiber mass content (Wf) | ISO 1172:1996 | % | **85.3** | — |
| Fiber volume content (Vf) | ISO 1172:1996 | % | **72.5** | — |
| Laminate density | ISO 1183-1 | g/cm³ | **2.17** | — |

### 2.2 Tension-Tension fatigue (ISO 13003:2003)

Tested at load ratio R = 0.1 (tension-tension), sine wave at 5 Hz, 23 °C / 50 % RH. Specimen waisted gauge per ISO 13003. The S-N curve is fitted as $\sigma_a = A \cdot N^{-1/m}$; the slope exponent and statistical evaluation are:

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|---|---|
| **Slope exponent m** | 8.51 |
| **A (stress amplitude at N = 1)** | 957 MPa |
| **Coefficient of correlation** | –0.993 |
| **Goodness of fit** | 0.985 |
| **Statistical model** | P95 / P5 S-N curves at 95 % confidence |

***Design table — predicted stress amplitude $\sigma_a$ and maximum stress $\sigma_{max}$ at target life N.*** *P50 column is the 50 % survival probability fit; P95 column is the 95 % survival / 95 % confidence design line.*

| N (cycles) | P50 σa [MPa] | P50 σmax [MPa] | P95 σa [MPa] | P95 σmax [MPa] |
|---|---|---|---|---|
| $1.0 \times 10^3$ | 424.8 | 944.0 | 382.3 | 849.6 |
| $1.0 \times 10^4$ | 324.1 | 720.1 | 291.7 | 648.2 |
| $1.0 \times 10^5$ | 247.2 | 549.4 | 222.5 | 494.5 |
| $1.0 \times 10^6$ | 188.6 | 419.1 | 169.8 | 377.2 |
| $1.0 \times 10^7$ | 143.9 | 319.8 | 129.5 | 287.8 |
| $1.0 \times 10^8$ | 109.8 | 244.0 | 98.8 | 219.6 |

At $10^7$ cycles — the typical fatigue design life used in wind-blade certification — the P95 design line predicts $\sigma_a \approx 130$ MPa with a corresponding maximum stress of 288 MPa. Designers applying DNVGL-ST-0376 partial safety factors should use the P95 values together with material partial factors $\gamma_m$ and the appropriate environmental knock-down factors.

## 3. WE-C100 — CFRP pultruded laminate

WE-C100 is a unidirectional carbon / epoxy pultruded laminate intended for spar caps in large wind blades where bending stiffness and lightweight are the dominant constraints. Reinforcement is 48K industrial-grade carbon roving; the matrix is a wind-grade epoxy system. The laminate is characterised under static loading across tension, compression, in-plane shear, interlaminar shear, and flexure, with DSC-determined glass transition temperature.

### 3.1 Physical properties

| Property | Standard | Unit | Avg | Rk (DNVGL-ST-0376) |
|---|---|---|---|---|
| Fiber mass content (Wf) | ISO 14127:2008 | % | **70.4** | — |
| Fiber volume content (Vf) | ISO 14127:2008 | % | **62.3** | — |
| Laminate density | ISO 1183-1 | g/cm³ | **1.58** | — |
| Glass transition Tg (DSC, half-step) | ISO 11357-2:2020 | °C | **116** | — |

### 3.2 Static mechanical properties

Tested at 23 °C / 50 % RH after at least 24 h conditioning. The **Avg** column reports the mean over the test panel. The $\mathbf{R_k}$ column is the characteristic value calculated per DNVGL-ST-0376 (Edition December 2015), Section 5 — i.e. the 95 % survival / 95 % confidence one-sided tolerance bound that blade designers feed into laminate analysis. GL 2010 characteristic values are also available on request.

| Property | Standard | Unit | Avg | Rk (DNVGL-ST-0376) |
|---|---|---|---|---|
| 0° Tensile strength | ISO 527-5:2021 | MPa | **1920** | 1690 |
| 0° Tensile modulus | ISO 527-5:2021 | GPa | **147** | 142 |
| 0° Tensile strain at break | ISO 527-5:2021 | % | **1.23** | 1.14 |
| Poisson's ratio (0°) | ISO 527-5:2021 | — | **0.35** | 0.30 |
| 90° Tensile strength | ISO 527-5:2021 | MPa | **63.8** | 58.5 |
| 90° Tensile modulus | ISO 527-5:2021 | GPa | **8.42** | 7.85 |
| 0° Compressive strength | ISO 14126:1999 | MPa | **1480** | 1350 |
| 0° Compressive modulus | ISO 14126:1999 | GPa | **135** | 128 |
| 90° Compressive strength | ISO 14126:1999 | MPa | **164** | 162 |
| 90° Compressive modulus | ISO 14126:1999 | GPa | **8.96** | 8.64 |
| V-notched rail shear (90°) | ASTM D7078 | MPa | **73.0** | 70.9 |
| In-plane shear modulus G12 | ASTM D7078 | GPa | **5.16** | 4.88 |
| Interlaminar shear strength | ISO 14130:1997 | MPa | **70.2** | 66.4 |
| 0° Flexural strength | ISO 14125:1998/A1:2011 | MPa | **1760** | 1550 |
| 0° Flexural modulus | ISO 14125:1998/A1:2011 | GPa | **139** | 135 |

## 4. Quality basis

All values in this datasheet were obtained on production-grade pultruded laminate specimens by an independent third-party laboratory accredited under the DNV·GL renewables-certification scheme. Test methods, instrumentation, conditioning and specimen preparation conform to the standards cited in each row.

Characteristic values reported in the right-most column are calculated using the DNVGL-ST-0376 (Rotor Blades for Wind Turbines, Edition December 2015) statistical method. The GL 2010 (Guideline for the Certification of Wind Turbines, Edition 2010) method is also supported and available on request.

## 5. Standards referenced

**Static mechanical:** ISO 527-5:2021 (tension, fibre-reinforced plastic composites — unidirectional), ISO 14125:1998/Amd.1:2011 (flexure), ISO 14126:1999/Cor.1:2001 (in-plane compression), ISO 14130:1997/Cor.1:2003 (apparent interlaminar shear), ASTM D7078 (V-notched rail shear). **Fatigue:** ISO 13003:2003. **Physical / thermal:** ISO 1172:1996 and ISO 14127:2008 (fibre content by calcination / digestion), ISO 1183-1 (density), ISO 11357-2:2020 (glass transition temperature by DSC). **Certification framework:** DNVGL-ST-0376 (Dec 2015), GL 2010 Guideline for the Certification of Wind Turbines.

## 6. Application notes

**Spar-cap design.** Pultruded carbon laminates such as WE-C100 are typically stacked into the spar cap of the blade as long, full-length plies. Bonding to the blade shell is via wind-grade epoxy adhesives; consult F1 Composite engineering for surface-preparation specifications and adhesive compatibility data.

**Environmental knock-downs.** The characteristic values in this datasheet reflect dry-conditioned room-temperature testing. Blade designers should apply the environmental, geometric and statistical partial safety factors specified in DNVGL-ST-0376 ($\gamma_{Mb}$ matrix dominated, $\gamma_{Mb}$ fibre dominated, $\gamma_{Mc}$ for compressive failure modes).

**Project-specific certificates.** Material Test Certificates (MTC) tied to a specific pultrusion lot are issued at point of order and carry the laminate panel ID, traceable fibre and resin batch numbers, and individual specimen results.

## 7. Disclaimer

*This datasheet is published by F1 Composite as engineering reference data for blade designers, certification bodies, and procurement teams. Values are typical and characteristic for the panel under test and are not a guaranteed batch-level result. Project compliance is established by the lot-specific MTC together with project-specific qualification testing as required by the certification body.*

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